purple, and purplish red. Clear yellow, and all shades of green and blue colours, are rarely, if ever, met with. These facts indicate that the deep sea is illuminated only by the sea-green sunlight that has passed through a vast stratum of water, and therefore lost all the red and orange rays by absorption. The transmitted rays of light could not be reflected by the animals referred to, and therefore they would be rendered invisible. Their bright colours can only become visible when they are brought up into the white sunlight. These bright colours are therefore just as much protective as the dull and black colours of other species.

The deep-sea star-fishes are nearly all orange, orange-red, or scarlet, even down to three thousand fathoms. The larger ophiurans are generally orange, orange-yellow, or yellowish white, the burrowing forms being usually whitish or mud-coloured, while the numerous species that live clinging to the branches of gorgonians and to the stems of Pennatulacea are generally orange, scarlet, or red, like the corals to which they cling. Among such species are *Astrochele lymani*, abundant on the bushy orange gorgonian coral, *Acanella normani*, often in company with several other orange ophiurans belonging to Ophiacantha, &c. *Astronyx loveni* and other species are common on Pennatulacea, and agree very perfectly in colour with them. These, and numerous others that might be named, are instances of the special adaptations of colours and habits of commensals for the benefit of one or both. Many of the large and very abundant Actiniæ, or sea-anemones, are bright orange, red, scarlet, or rosy in their colours, and are often elegantly varied and striped, quite as brilliantly as the shallow-water forms; and the same is true of the large and elegant cup-corals, *Flabellum goodei*, *F. angulare*, and *Caryophyllia communis*,—all of which are strictly deep-sea species, and have bright orange and red animals when living. The gorgonian corals of many species, and the numerous sea-pens and sea-feathers (Pennatulacea), which are large and abundant in the deep sea, are nearly all bright coloured when living, and either orange or red. All these Anthozoa are furnished with powerful stinging organs for offence and defence; so that their colours cannot well be for mere protection against enemies, for even the most ravenous fishes seldom disturb them. It is probable, therefore, that their invisible colours may be of use by concealing them from their prey, which must actually come in contact with these nearly stationary animals in order to be caught. But there is a large species of scale-covered annelid (*Polynoë aurantiaca*, Verr.) which lives habitually as a commensal on *Bolocera tuediæ*, a very large orange or red actinian, with unusually powerful stinging organs. Doubtless the worm finds, on this account, perfect protection against fishes and other enemies. This annelid is of the same intense orange colour as its actinian host. Such a colour is very unusual among annelids of this group, and in this case we must regard it as evidently protective and adaptive in a very complex manner.

It has been urged by several writers, that the light in the deep sea is derived from the phosphorescence of the animals themselves. It is true that many of the deep-sea Anthozoa, hydroids, ophiurans, and fishes are phosphorescent; and very likely this property is possessed by members of other groups in which it has not been observed. But, so far as known, phosphorescence is chiefly developed in consequence of nervous excitement or irritation, and is evidently chiefly of use as a means of defence against enemies. It is possessed by so many Anthozoa and acalephs which have, at the same time, stinging organs, that it would seem as if fishes had learned to instinctively avoid all phosphorescent animals. Consequently it has become possible for animals otherwise defenceless to obtain protection by acquiring this property. It is well known to fishermen that fishes avoid nets, and cannot be caught in them, if phosphorescent jelly-fishes become entangled in the meshes; therefore it can hardly be possible that there can be an amount of phosphorescent light, regularly and constantly evolved by the few deep-sea animals having this power, sufficient to cause any general illumination, or powerful enough to have influenced, over the whole ocean, the evolution of complex eyes, brilliant and complex protective colours, and complex commensal adaptations.

It seems to me probable that more or less sunlight does actually penetrate to the greatest depths of the ocean in the form of a soft sea-green light, perhaps at two thousand to three thousand fathoms equal in intensity to our partially moonlight nights, and possibly at the greatest depths equal only to starlight. It must be remembered that in the deep sea, far from land, the water is far more transparent than near the coast. A. E. VERRILL

ARTIFICIAL LIGHTING[1]

IN early times but a small fraction of our forefathers' lives was spent under artificial light. They rose with the sun and lay down to rest shortly after sunset. During the long winter evenings they sat round the fire telling stories and singing songs of love and war; the fire-light was sufficient for them, except occasionally during grand feasts and carousals, when their halls were lighted by pine-wood torches or blazing cressets. But, as a rule, after sunset they lived in semi-darkness.

From that early period, as man has advanced in civilisation, in the thirst for knowledge derived from books, and in following the gentler pursuits which demand an indoor life, there has been a steady increase in that fraction of our lives which is spent under light other than that of the sun. But the improvement in the quality of the artificial light has been very slow. The ruddy lights and picturesque shadows so faithfully handed on to us by Rembrandt's pictures show us very graphically what our poets have called "the dim glimmer of the taper" of those days. A few years before the introduction of gas, Argand, by his improvements in the burners of oil lamps, enabled our fathers to see for the first time a comparatively white light, but as far as the matter we to-day propose to discuss is concerned, viz. the effect of artificial lighting, and more particularly electric lighting, on our health, we need only consider the reign of artificial light as it commenced with the general use of gas and petroleum, for then and only then could it be said to affect our health.

Prior to the introduction of the electric light we have been accustomed to consider every hour spent under artificial light as an hour during which all conditions are less favourable to perfect health than they would be during daylight. Can we now hope to ameliorate this condition of things through the agency of electricity? Before we can discuss this question I must point out to you the chief differences which exist between hours of work or recreation spent in daylight and under artificial light. In the former case we live in abundance of light. The sunlight itself exercises a subtle influence on our bodies; that mixture of heating and chemical rays which when analysed form the solar spectrum, and combined form the pure white light of daylight, is needed to enable all animal and vegetable organisms to flourish in the fullest conditions of healthful life.

In nearly all cases when the sun is up, the functions of life are in the state of fullest activity, and when it sets they sink into comparative repose. In daylight life wakes, in darkness life sleeps. In addition to the abundance of pure white light, the heat attending is only that necessary for health. The air remains unvitiated, except by our own breathing. On the other hand, when working under artificial light, we have these conditions all altered in degree:

1. We have an insufficient light; a scale of lighting by gas or by electricity which would be pronounced excessive at night-time is still far inferior to average daylight.

2. All artificial lights, whether produced by combustion, as in the case of candles, oil, gas, and petroleum, or by the incandescence of a conductor by the means of electricity, produce heat; this heat, in proportion with the light afforded, is enormously in excess of the heat given by sunlight. Electricity, as you will see hereafter, is far the best in this respect, but even it is inferior to sunlight.

3. All these same illuminants, excepting electricity, contaminate the air and load it with carbonic acid, sulphur, and other compounds—all injurious to the health and to the general comfort of the body. It will be convenient to consider the effects —first, on our health generally; second, on our eyesight in particular. I have already called your attention to the fact that that proportion of coloured rays which, when combined, form white sunlight, is that best suited to healthy life. It is necessary too to that sufficient and proper stimulus to the organic changes which go on in our bodies, and which we call a state of good health. The various artificial lights differ very widely from sunlight in this respect, that they are all more or less deficient in the rays at the violet end of the spectrum, commonly called the actinic rays, and which most probably exercise a very powerful effect on the system. It is the want of a due portion of these violet rays which makes all artificial light so yellow. Even the light of the electric arc, which is richer in these rays than any other, is still on the yellow side of sunlight. The incandescent electric light is next best in this respect; next in order come gas, petroleum, and the various oil lamps. No doubt some of you will

[1] Lecture delivered at the Health Exhibition by Mr. R. F. B. Crompton

challenge my statement that the electric arc is yellow. It has always been called a cold blue light. It is not so; it is only by comparison with the yellower light of gas or with the incandescent lamps that it appears blue; when compared with the sunlight reflected from a white cloud it will be seen to be distinctly yellow in tinge; but still both classes of electric light are far superior to all others in nearest approaching the white light of daylight, and thus satisfying the actinic action which our bodies demand.

Turning now to the comparative heating and air-vitiating properties of artificial lights which we shall find it convenient to take together, I have here a table (Table A) prepared by Dr.

TABLE A.—*Showing the Oxygen consumed, the Carbonic Acid produced, and the Air vitiated, by the Combustion of certain Bodies burnt so as to give the Light of* 12 *Standard Sperm Candles, each Candle burning at the rate of* 120 *grains per hour*

Burnt to give light of 12 candles, equal to 120 grains per hour	Cubic feet of oxygen consumed	Cubic feet of air consumed	Cubic feet of carbonic acid produced	Cubic feet of air vitiated	Heat produced in lbs. of water raised 10° F.
Cannel Gas....	3·30	16·50	2·01	217·50	195·0
Common Gas..	5·45	17·25	3·21	348·25	278·6
Sperm Oil......	4·75	23·75	3·33	356·75	233·5
Benzole.........	4·46	22·30	3·54	376·30	232·6
Paraffin.........	6·81	34·05	4·50	484·05	361·9
Camphine......	6·65	33·25	4·77	510·25	325·1
Sperm Candles	7·57	37·85	5·77	614·85	351·7
Wax............	8·41	42·05	5·90	632·25	383·1
Stearic...........	8·82	44·10	6·25	669·10	374·7
Tallow..........	12·00	60·00	8·73	933·00	505·4
Electric Light.	none	none	none	none	13·8

Meymott Tidy, which shows the oxygen consumed, the carbonic acid produced, the air vitiated, and the heat produced by the combustion of certain bodies burned so as to give the light of twelve standard candles, to which Mr. R. Hammond has added the heat produced by a 12-candle incandescent electric lamp. From these figures you will see that the air of a room lighted by gas is heated twenty times as much as if it were lighted to an equal extent by incandescent electric lamps. When arc lamps are used, the comparison is still more in favour of electricity. You will be surprised to see from the table that our old friend the tallow candle, and even the wax candle, is far worse than gas in the proportion of air vitiated and heat produced, and you will be disposed to disbelieve it; but the fact is, that so long as candles were used light was so expensive that we were obliged to be content with little of it; in fact we lived in a state of semi-darkness, and in this way we evaded the trouble. It is only since the general introduction of gas and petroleum that we have found what an evil it is.

It is not unusual, in fact it is almost invariable, for us to find the upper stratum of air of the rooms in which we live heated to 120° after the gas has been lighted for a few hours. We have grown accustomed to this state of things, and are not surprised that when we take the library ladder to get a book from the upper shelf we find our head and shoulders plunged into a temperature like that of a furnace, producing giddiness and general malaise. If you look again at the table you will see that each gas burner that we use consumes more oxygen and gives off more carbonic acid, and otherwise unfits more air for breathing, than one human being, and it is this excessive heating and air vitiation combined which are the main causes of the injury to the health from working long hours in artificial light. I could go on for a long time giving instances of the fearful state of the atmosphere of our large public buildings as well as of our private homes after the gas has been lighted for a few hours, but this paper is not intended as an onslaught on gas; moreover these ills are so well known to nearly all of you that I need not bring them more prominently before you. I will only take one instance, viz. that of the Birmingham Town Hall, which has been lighted alternately by gas and electricity.

During the grand Birmingham Musical Festival, which was held in that hall two years ago, some careful experiments were made to show how the orchestra and audience in the hall were affected by the two kinds of lighting. The gas lighting was in the form of several huge pendants suspended down the centre of the hall. The electric lighting was in the form of clusters of lights placed on large brackets projecting from the side walls with two central pendants placed between the gas pendants. The candle-power given by the electric light was about 50 per cent. in excess of that given by the gas light; the degree of illumination by electricity was consequently very brilliant.

It was found that when the gas was used the temperature near the ceiling rose from 60° to 100° after three hours' lighting. The heating effect of the gas was, therefore, the same as if 4230 persons had been added to the full audience and orchestra of 3100. Similarly the vitiation of the air by carbonic acid was equal to that given off by the breathing of 3600 additional persons added to the above audience of 3100. But on evenings when the electric light was used the temperature only rose 1½° during a seven hours' trial, and the air, of course, was only vitiated by the breathing of the audience. The further experiment was tried of giving to every member composing the large orchestra a printed paper of questions asking how the new mode of lighting affected him or her personally, and I have here 265 replies to those questions. They are very interesting. I will read a very few of them out to you. From this you will learn that without exception the comfort and general well-being of this large orchestra was increased enormously by the use of the new illuminant, yet it is reasonable to suppose that the comfort of the audience was increased in an equal degree. Now we all of us know that the times when we suffer most from the effect of artificial light is in crowded places of public amusement, which are at the same time brilliantly lighted. Many of us are unable to go to the theatre or to attend evening performances of any kind, as the intense headache which invariably attends through staying a single hour in such places entirely prevents them. This headache we commonly say is inseparable from the heat and glare of the gas. Now this phrase is not strictly correct. It is no doubt due to the heat of the gas and its air-vitiating properties, but when we use the word glare I believe we refer to the effect the gaslight has upon our heads, and which effect is not due to excess of light. On the contrary, I believe if a far greater amount of light be given by the electric light without the heating and air vitiation being present such headache is never produced, although some of the more tender-headed amongst us will at first complain of the glare because they are habituated to associate plenty of light with great heat, great air vitiation, and other evils.

Indeed, so long have we been accustomed to closely associate brilliant artificial light with headache and glare, that we who are introducing electric light are most cautious not to give the full quantity of light which we could afford to give, and which would afford the greatest rest to the eye and greatest bodily comfort. I now come to the effect that light has upon the temperament. If we try the experiment in an assemblage of people of gently decreasing the lighting of the room, it will be found that the spirits of every one will be depressed just as the light is depressed, and, *vice versâ*, their spirits will be raised just as the light is raised. I have many times, when conducting experiments of electric lighting on a large scale, noticed this fact, and I have been led to the conclusion *that during hours of waking every person is benefited by increase of light up to the extent of full sunlight*, providing that this high degree of lighting is not attended by heat and by air vitiation; and I must add that the source of light must not be from one or two brilliant points only, but it must be well regulated and not such as to cause dark, deep shadows.

This leads me on to the subject of the effects on the eyesight of the electric light as compared with other lights. *Healthy eyesight demands a plentiful supply of light. It is the greatest mistake to suppose that a state of semi-darkness is good* for our eyes, unless they are defective, or recovering from the effects of past injury or disease. Whoever saw a painter, engraver, printer, watchmaker, or indeed any one the quality of whose work depends on the excellence of his eyesight, who did not desire a flood of pure white light thrown on to his work. I think I have the authority of oculists when I say that 19-20ths of the diseases of the eyes arise from working the eyesight long hours with insufficient light. Again, another great cause of injury to eyesight is the unsteadiness of most artificial lights. Much improvement has been made in the light of gas during the

last few years by the introduction of argand burners, and globes for the flat gas burners having much larger lower openings, so that the dancing and flickering batswing burner of five years ago is not so common in a good house. Even the steadiest of the modern gas burners is extremely unsteady as compared with the light of the incandescent electric lamp. Those of you who have been to the Savoy Theatre will have noticed the effects of the lights behind the scenes on the scenery itself. The light is so absolutely steady that it is comparable to sunlight. Hitherto I have said nothing as to the comparative excellence of the two forms of electric light, viz. the electric arc and the incandescent lamp. Both have their proper places. The arc light, which is the whitest in colour and most economical to produce, is not so steady as the incandescent lamp. It is therefore unsuitable for indoor use or for reading by, or for such occupations as require the maximum of steadiness. But it is well suited for the lighting of large buildings and public places. I am unaware if any experiments have been made as to the effects of brilliant arc lighting on the eyesight of men who have to work night shifts, as although the opinion of the workmen who have to work under it is unanimous in its favour, yet that opinion is more based on their personal comfort, due to their being able to carry on their work with facility almost equal to that given by daylight. The large sorting rooms at the General Post Office at Glasgow have been for a long time lighted by the arc light, and with a most beneficial result to the health and eyesight of the letter-sorters and telegraph clerks. The former occupation is one which tries the eyesight very severely. The public generally does not know how the habit of writing the addresses on envelopes with pale ink and blotting it off rapidly before it has time to darken tries the eyesight of the Post Office letter-sorters. So long as gas is used, a powerful burner has to be brought very close to the head of the sorter, and under such conditions the eyesight fails at an early age. At Glasgow Post Office I am able to boast that by the introduction of the electric light I enabled many of the more aged sorters who were commencing to use spectacles to do without them—and even I put back the clock of time in enabling several who had used them for some years to disclaim them. I am aware that it has been alleged by the opponents of the electric light, whether interested or otherwise, that in many cases the intensity of the light has injured eyesight. I do not think any such cases can be substantiated. Many of us who are in the habit of experimenting with powerful arc lamps have had our eyelids temporarily affected by incautious exposure at too short a distance. Again, over and over I meet with the complaint that if I stare at an arc lamp for a long time it will make my eyes ache; the obvious retort being, Why should you stare at the light? If you do the same with the sun, you will be equally inconvenienced. Before such an audience as this, which is of course familiar with the beautiful electric lighting in the Health Exhibition itself, it is useless for me to enlarge on the many conditions of the electric light as it indirectly affects health. I may only name the many additional pleasures of the eye we get from its use. Our flowers in our rooms do not fade away, and are seen in their true colours. Our pictures or all coloured objects are seen to better advantage. I may mention one thing which would not generally occur to you, that in London certainly an electric-lighted house can be cleaned properly in winter. You may smile at this, but I assure you that the advantage of being able to turn a flood of light into your drawing-rooms and dining-rooms at six o'clock on a winter's morning, so that the whole of the cleaning can be finished as thoroughly as if done by daylight, before the family comes down to breakfast, is one that must be experienced before it can be thoroughly appreciated. Again, the advantage to the health of our children is simply inestimable. No night-lights, matches left about, or gas turned down low are required. A child six years old can be trusted to press a button and so turn the light off or on; the lamps being high and out of reach are not easily broken or over-turned, and the air of the children's nursery, even if the light be kept burning the night through, remains pure throughout. Another indirect advantage due to the absence of heat is that it is comparatively easy to thoroughly ventilate and cool during the hot weather a room lighted by the electric light. The heat of gas placed high in the room causes such intense draughts when the windows are open that the discomforts and dangers of the draughts are almost worse than the discomfiture from the heat and vitiated air, whereas in an electric-lighted room there is no difficulty in opening wide all the windows, the draughts produced being so gentle as to be hardly felt.

SOCIETIES AND ACADEMIES

London

Physical Society, June 28.—Prof. Guthrie, President, in the chair.—New Member, Mr. W. H. Hensley.—Lord Rayleigh made a communication on the practical use of the silver voltameter for the measurement of an electric current. On a former meeting of the Society the method was explained by the author, but on the present occasion the apparatus was exhibited. The author considers this the best method of determining the strength of current in absolute measure. One ampere deposits 4 grammes of silver in an hour; therefore a quarter to half an hour is sufficient to give 1 or 2 grammes, quantities which can be measured with accuracy. Any current from 1/10 to 4 or 5 amperes can be measured successfully in this way. With very weak currents there is a difficulty in weighing the deposits; with very dense currents the deposit is apt to be irregular. The author deprecates the use of acetate of silver, pure nitrate or pure chlorate of silver giving the best results. The cathode of his apparatus is a platinum bowl, the anode a silver sheet wrapped with clean filter paper sealed over it to keep any loose silver from dropping on the cathode. The anode is immersed in the solution of silver salt; and at the end of several hours (if great accuracy is required) a measurement of the weight of silver deposited is made by weighing the bowl cathode in a chemical balance. Dr. Fleming inquired whether it was not better to weigh the loss of weight suffered by the anode, as is sometimes done. Lord Rayleigh had not found this plan so good, the anode being apt to disintegrate and lose weight, not by true electrolytic action. Prof. Guthrie remarked that with small electrodes peroxide of silver is formed, and that the inferiority of acetate of silver might be due to formation of subacetate.—Lord Rayleigh then made a communication on a colour-mixing apparatus founded on refraction. This apparatus had been described at a former meeting of the British Association, and consists of a double-refracting prism, a lens, dispersing prism, and screen, by which an overlapping of spectra can be obtained, and thus a mixture of colours. In comparing different eyesights with it Lord Rayleigh finds that the majority of persons are more sensitive to red than he himself. In answer to Mr. W. Baily he had not observed any difference between the two eyes of the same person, except what might be due to fatigue and freshness. Dr. Guthrie inquired if the author had discovered any racial characteristics of colour-blindness. Lord Rayleigh had not observed any so far. Dr. Guthrie stated that, though colour-blind to red, he believed he was more than usually sensitive to blue. Dr. Stone and Mr. Stanley referred to known cases of blindness to green, as well as red. Dr. Lodge asked if persons abnormally sensitive to red could see further down the spectrum. Lord Rayleigh believed they could see the spectrum brighter near its limits at all events. Mr. Glazebrook briefly described a modification of Lord Rayleigh's apparatus by which the distance on the spectrum which any one can see could be measured.—Mr. C. V. Boys read a paper on a phenomenon of electromagnetic induction. Between the poles of an electro-magnet a small disk of copper is hung by a bifilar suspension. If the magnetic field is uniform, and the disk at an angle to the lines of force, then on making the magnet it is jerked parallel with the lines of force. If it is a changing field, and the disk perpendicular to the lines of force, it is repelled on making the magnet and attracted on breaking by the nearest pole. This phenomenon, which was observed by Faraday, was shown by Mr. Boys to be useful for determing the intensity of a magnetic field by measuring the throw of the disk on magnetising and demagnetising. It might also be employed to measure the resistance of bodies in the form of plates, from their diameter, moment of inertia, and observed throw. Any structural difference of resistance in different directions in the body might be determined by its means. Mr. Boys illustrated his remarks with curves of results obtained by experiment. Lord Rayleigh considered that the effect of self-induction on the results was not likely to be serious.—Mr. J. Hopps read a paper on the alteration of electrical resistance in metal wires produced by coiling and uncoiling. His experiments were made with an inclined plane, the angle of which could be varied, and a car, carrying bobbins, which was drawn up or let down the plane by the wires experimented on. It appeared that coiling and uncoiling tends to produce hardness in a wire. Coiling produces an increase of resistance, and uncoiling a decrease in the resistance of a wire.—Mr. R. T. Glazebrook, M.A., F.R.S., read a paper on the determination